# UNITED STATES PROVISIONAL PATENT APPLICATION

**Title:** Systems and Methods for the Production of Electrets and Magneto-Electrets
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## BACKGROUND OF THE INVENTION

Electrets are dielectric materials that maintain a quasi-permanent electric charge or dipole polarization. They can either be bipolar or monopolar depending upon the method used in their production. They are used in various applications, including microphones, sensors, energy harvesting devices (such as triboelectric nanogenerators or TENGs), electrostatic filters, and other systems that leverage their ability to retain static charges. Traditionally, electrets are created by embedding charges into dielectric materials via corona discharge or by heating the material and allowing it to cool under the influence of a relatively high voltage applied across the material. However, conventional methods face several limitations in terms of charge density, polarization, stability, and scalability. Electrets which also have traditional magnetic field characteristics (referred to as "magneto-electrets" in this application), are also not conventionally available, although there may be certain applications where contemporaneous static electric and magnetic fields are desirable.

### Challenges in Electret Production

Producing electrets with high charge density and stability has always been a challenge. Conventional methods often result in limited charge retention and degradation over time due to environmental factors such as moisture or temperature changes. Traditional electrets that are produced with the application of high voltage across the dielectric material are generally "bipolar" in nature (possessing both a positive and negative charge) when it may be desirable, in certain applications, that the electret be either positive or negative in charge (monopolar). Additionally, many electrets are not adaptable for high-performance or extreme condition applications. For example, standard polymer-based electrets are often unable to meet the performance requirements for high-temperature or high-precision applications, limiting their use in advanced industrial and scientific applications.

### Recent Advancements

Recent developments in triboelectric nanogenerators (TENGs) and materials science have renewed interest in triboelectric effects which can be beneficial for producing electrets. The triboelectric effect, where materials generate an electric charge upon frictional contact with other materials, offers a scalable and cost-effective approach for electret production. Advances in material engineering, particularly the use of nano-materials and novel polymers, have opened the door to producing electrets with improved performance characteristics. Nonetheless, these advancements have not fully solved the problems of charge density, polarization, stability, and flexibility in electret production, especially for applications which integrate the use of traditional magnetic fields in unison with the electric fields.

## SUMMARY OF THE INVENTION

The present invention relates to systems and methods for producing monopolar electrets, as well as bipolar electrets and magneto-electrets. Through a combination of triboelectric effects, optimized

material choices, advanced charging techniques, and the application of static, alternating, or pulsed electromagnetic fields during the various stages in the production of the electrets / magneto-electrets, the invention enables the development of electrets and magneto-electrets with enhanced charge density and retention, memory properties, field orientation customization, and structural modifications in their lattice configuration.

### Need for Increased Surface Area and Advanced Charging Techniques

In order to increase the charge density and stability of electrets, a need has arisen for innovative materials that offer a higher surface area for charge generation. Granular, powdered, or nano-particle triboelectric materials, such as silicon dioxide ($SiO_2$) and polytetrafluoroethylene (PTFE) for example (being opposite to each other in the triboelectric series), have emerged as key components in optimizing triboelectric charging. These materials offer significantly increased surface area compared to bulk materials, providing more contact points and improving the overall efficiency of the charge transfer process. Such granular, powered, or nano-particle triboelectric materials (referred to as "Aggregates" in this application) can significantly increase the charge density of an electret.

Additionally, traditional triboelectric charging processes rely on simple contact-separation methods. However, there is growing recognition that alternative charging techniques, such as tumbling systems, acoustic or mechanical vibration / shaking systems, fluidized beds, and exposure to UV light, microwave, or other forms of electromagnetic radiation (such as x-rays) can be used to further optimize the charge accumulation and retention of the Aggregates. Binding materials, which will be discussed in the following sections of this application, can be applied to the charged Aggregates in order to secure their lattice positions and charge retention within the electrets. Conventional magnetic materials (or materials which are both dielectric and magnetic in nature) can also be used as the Binders and/or Aggregates during the production stages of the electrets / magneto-electrets.

## DETAILED DESCRIPTION OF THE INVENTION

### Overview

The present invention pertains to advanced systems and methods for producing electrets and magneto-electrets with enhanced performance characteristics. This includes the production of monopolar electrets, bipolar electrets, and magneto-electrets through a combination of novel materials, optimized charging techniques, and innovative production methods. The invention also introduces methods to induce structural modifications and memory effects in the electrets / magneto-electrets using applied electromagnetic fields during the various stages of the production process.

Briefly stated, the systems and methods for the production of electrets / magneto-electrets disclosed consists of taking charged granular, powdered or nano-particle "Aggregates" and applying a solidifying agent that is capable of securing the Aggregates to each other while maintaining their charge (referred to in this application as a "Binder"). Magnetic materials can also be used as the Aggregate and/or Binder in each of the stages of production, using methods well known in the art for optimizing their magnetic flux density. The use of magnetic materials (bulk, powdered, etc) can be used for the production of what will be referred to as magneto-electrets, which have both an electric and magnetic field contemporaneously. The application of static, alternating, or pulsed electromagnetic fields during the production stages can also modify the lattice configuration or optimize the charge / flux retention of the electrets / magneto-electrets leading to novel applications.

**Aggregates and Binders**

1. **Aggregates (including, but not limited to)**:
    - **Granular, Powdered, or Nano-Particle Triboelectric Materials**: These materials, including, but not limited to, silicon dioxide ($SiO_2$) and PTFE for example (being opposite to each other in the triboelectric series), are used to maximize the surface area available for triboelectric interactions. The increased surface area enhances the charge density of the electrets. Nano-scale particles of these materials create numerous contact points during the triboelectric process, leading to higher charge accumulation and retention.
    - **Electrical Conductors and Semiconductors**: In some applications, it may be beneficial to use granular, powdered, or nano-particle electrical conductors and/or semiconductors. For example, an allotrope of carbon (being a semiconductor) could be sandwiched between zinc and copper powder (being opposite to each other in the triboelectric series). Due to the mobility of electrons in these conductors / semiconductors, they may be mixed with a triboelectric material to help retain their charge.
    - **Neutrally Charged Materials**: In some applications (such as in the production of bipolar or other multiple polar electrets / magneto-electrets) it may be desirable to use a neutrally charged material (such as wood pulp or sodium chloride for example) as a separator between the positively and negatively charged Aggregates.
    - **Magnetic Materials**: Conventional magnetic materials that are commonly known in the art (bulk, powered, etc) can also be used as Aggregate materials. The magnetic Aggregate may also have dielectric characteristics.

2. **Binders (including, but not limited to)**:
    - **Geopolymer Binders**: Derived from kaolin or other aluminosilicate sources, these binders provide high thermal stability and are suitable for extreme conditions.
    - **Epoxy or other Resin-Based Binders**: Offer excellent mechanical strength, chemical resistance, and versatility for complex manufacturing requirements.
    - **Wax-Based Binders**: Used in the first formulations of “conventional” electrets.
    - **Polymer-Based Binders**: Polymers such as PTFE and polyurethanes offer flexibility and cost-efficiency while enhancing triboelectric performance.
    - **Magnetic Binders**: Conventional magnetic materials that are commonly known in the art can also be used as Binding materials.
    - **Ceramic-Based Binders**: Used in high-temperature or high-insulation applications, offering robust thermal and electrical properties.

Through experimentation it may be found that there are certain Binders which are more favorable for the production of either a positively or negatively charged electret / magneto-electret. In some cases, two or more binders can be used for the production of electrets / magneto-electrets depending upon the application. In general, any Binder which is capable of securing the Aggregates together while also maintaining their charge / flux can be used. In some situations, such as with the use of tubing, a Binder may not even be necessary if the Aggregates can be compacted together for example. In such as situation, other alternatives to a Binder such as, but not limited to, an Electrolyte may be used instead.

**Aggregate Charging Process**

1. **Basic Charging Method**: Traditional triboelectric charging involves bringing a material into contact with a triboelectric partner material and then separating them. The resulting frictional interaction generates static charges on the surfaces. Parameters such as contact pressure, separation speed, and surface roughness are controlled to optimize the charging process. Conventional methods that are well known in the art for optimizing the flux density of magnetic materials can also be used to "magnetically charge" the materials.

2. **Enhanced Charging Techniques (including, but not limited to)**:
    - **Tumbling Systems**: This system / method involves placing the triboelectric materials in a rotating or tumbling device. The continuous frictional contact and separation during tumbling increase charge generation and are suitable for batch production. As an example, a powdered silicon dioxide Aggregate can be tumbled within a cylinder made of a material on the opposite end of the triboelectric series, such as PTFE.
    - **Acoustic/Mechanical Vibration Systems**: These systems subject the materials to vibrations / shaking, causing rapid contact and separation events. This technique enhances the efficiency of charge transfer and is beneficial for precision applications where control over material interaction is critical.
    - **UV Light / X-Ray Exposure**: Applying UV light / X-Radiation to the materials before or during the charging process modifies the surface properties, enhancing the material's ability to hold and retain charge. Radiation treatment can create surface states that capture charges more effectively. Any other forms of radiation, such as Alpha, Beta, or Gamma radiation for example, can also be used.
    - **Heat Treatments**: Pre-heating or maintaining materials at specific temperatures during charging improves molecular mobility, aiding in better charge alignment and retention. Heat also removes moisture, reducing the risk of charge leakage.
    - **Exposure to Other Forms of Electromagnetic Radiation**: Static, alternating, or pulsed electromagnetic fields may be applied in order to optimize the charge / flux retention of the electrets / magneto-electrets.

In each of these example charging techniques, the use of other techniques such as, but not limited to, the use of a vacuum environment, grounding, and rectification, may be incorporated. In general, any system / method which optimizes the electric charge / magnetic flux of the Aggregates can be used.

**Structural Modifications and Memory Effects**

1. **Static, Alternating, or Pulsed Electromagnetic Field Application**: The application of static, pulsed, or alternating electromagnetic fields can induce modifications in the lattice structure of the electrets / magneto-electrets. By applying the fields, it is possible to influence the alignment of molecules within the materials, creating memory effects, increasing the material's capacity or inductance, or enhancing the material's ability to retain electric charge or magnetic flux.

**Production of Monopolar Electrets**

A material on either end of the triboelectric series (positive or negative) can be used as an Aggregate with one of the previously mentioned charging methods and then made to set within a mold using one of the previously mention Binders. For example, silicon dioxide powder can be tumbled within a grounded and rectified PTFE cylinder to induce a positive charge on the Aggregate. The Aggregate can then be transferred to a mold where a Binder, such as Epoxy resin, is combined with the Aggregate to form a positively charged monopolar electret. Of course, it is also possible that this procedure is performed in reverse, where the Aggregate is combined to the Binder. In situations where both, the positive and negative Aggregates are used simultaneously in the charging technique (such as in the case with fluidized beds), electromagnetic fields may be used to separate the charged Aggregates for the production of monopolar electrets.

**Production of Bipolar Electrets**

1. **Combination of Monopolar Electrets**: Bipolar Electrets are created by integrating negative monopole electrets with positive monopole electrets. This combination results in a product with both positive and negative charge distributions, leading to a bipolar charge configuration. Bipolar electrets are useful in applications that require complex electric field configurations, such as in advanced sensors, actuators, and energy conversion devices.

2. **Layered Structures**: In some cases, bipolar electrets can be achieved by layering or arranging monopolar Aggregates / electrets in a specific configuration to create a composite material with bipolar properties. Neutrally charged dielectric or magnetic materials can also be used as a separator between the positively and negatively charged monopolar Aggregates / electrets. The use of electromagnetic fields can also be used to aid in the layering structure of the products.

**Production of Magneto-Electrets**

1. **Integration with Permanent Magnets**: The combination of electrets with conventional permanent magnets. This hybrid approach creates products where both electric and magnetic fields exist contemporaneously.

2. **The use of Magnetic Materials as Aggregates and/or Binders**: Conventional Magnetic materials and “magnetic flux charging” techniques can be used during the various stages of the magneto-electret production process (for example by the application of electromagnetic fields). The magnetic materials may also have dielectric characteristics.

3. **Design Considerations:** The integration of permanent magnets and/or magnetic materials requires careful design to ensure that the magnetic field interacts effectively with the electret's electric field. The strength and orientation of the fields, as well as the charge density of the electrets, are critical factors in optimizing the end product's performance.

**Applications**

The enhanced electrets and magneto-electrets disclosed are suitable for a variety of applications, including, but not limited to:

- **High-Sensitivity Sensors and Microphones**: Improved charge density and stability enhance the performance of electrostatic sensors and microphones.
- **Triboelectric Nanogenerators (TENGs)**: Higher charge density and efficiency in energy conversion.
- **Advanced Filtration Systems**: Enhanced electrostatic properties improve particle capture efficiency.
- **Focused Drug Delivery Systems**: The use of electrets / magneto-electrets can enhance the effectiveness for drug delivery systems.
- **Atmospheric Water Accumulation**: A negatively charged electret can attract atmospheric dew.
- **Precision Actuators and Hybrid Devices**: Combining electrets with magnetic fields for precise control and improved functionality in various devices.

**Conclusion**

The development of electrets has traditionally been limited by the materials and processes available, resulting in limitations in charge density, polarization, stability, and application versatility. However, through the use of granular, powdered and nano-particle materials (Aggregates), advanced charging techniques such as, but not limited to, tumbling and vibration systems, UV and heat exposure, and the application of electromagnetic fields during the various stages of the electret / magneto-electret production systems and methods disclosed, the present invention introduces a robust system for producing products with significantly improved performance characteristics.

Additionally, the integration of magneto-electrets expands the scope of applications, providing solutions for complex electric and magnetic field-dependent technologies. By addressing the limitations of traditional electret production methods, this invention opens up new possibilities for a range of industries, including, but not limited to, energy harvesting, environmental filtration, and precision instrumentation.

## ABSTRACT OF THE DISCLOSURE

The present invention provides comprehensive systems and methods for producing high-performance electrets / magneto-electrets through advanced triboelectric and other charging processes. Electrically and magnetically charged Aggregates are bound together with the use of Binding materials. It addresses the limitations of traditional electret and magnetic technologies by incorporating novel materials, optimized charging techniques, and innovative structural modifications to create monopolar, bipolar, and magneto-electrets with enhanced properties for modern industrial, scientific, and consumer needs.